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(54) **Tetraaxial woven fabrics and tetraaxial weaving machine thereof.**

(57) The present invention provides a tetraaxial woven fabric in a novel texture exhibiting isotropic nature superior to that of the triaxial woven fabric and is composed of warp ends, weft ends, and intersecting upper and lower bias yarns running obliquely to the former two under such circumstances as increasing demand for triaxial woven fabrics having isotropic nature in strength and elongation requisite to improvement in strength and reduction of weight of FRP and supply of materials suited to the manufacture of aircrafts and autocars. Further, for the purpose of weaving and tetraaxial fabric as above, the present invention provides a bias yarn feeding device and bias yarn traversing device in a structure that has never been devised before, thereby enabling high speed weaving and production at low cost of a fabric exhibiting high isotropic characteristics in spite of reduced thickness thereof.

EP 0 263 392 A2

Tetraaxial Woven Fabrics and Tetraaxial Weaving Machine thereof

Background of the Invention:

1) Industrial Field utilizing the Invention:

The present invention relates to a novel tetraaxial woven fabric composed of two kinds of bias yarns running in the crosswise direction and intersecting each other in addition to the ordinary warp and weft ends, and to a tetraaxial weaving machine therefor.

2) Prior Art:

A structure composed of warp ends or strands and crossing bias yarns or strands is found among old bamboo craftworks called "eight-eye interlacing" (YATSUMEAMI). Also, there is a structure in which tetraaxially directed yarns are put into mere stack relation and united into one body by the knitting machine, for example, Ruschel machine. However, it appears that a tetraaxial fabric woven by the weaving machine has not yet been found.

Triaxial woven fabrics, which have been called "bias woven fabrics" from the past and are woven of crossing bias yarns assumed as warp ends to be interlaced with weft ends, are still produced on a very small scale in the field of traditional craftword. This kind of bias woven fabric depends on manual weaving by means of a device in which the upper and lower reeds are reciprocated right and left at a distance equivalent to one stitch in the opposite directions so as to enter or return from the weaving area, whereby bias yarns are vertically shifted at the rate of one stitch in the opposite directions.

Recently, a triaxial woven fabric of net-like texture has been disclosed in the Utility Model Registration, Publication NO. Sho 45-11573, which is reported to be usable as materials for summer obi (a broad sash worn with a Japanese kimono), shawl, and curtain. More orthodox triaxial fabrics are disclosed in the Japanese Patents, Publication No. Sho 59-34812 (USP 3,999,578) and Sho 59-36015 (USP 4,015,637),however, in these fabrics, too, the upper and lower bias yarns are assumed as warp ends and subjected to shedding with the weft end run through the shed thus formed, the horizontal movement of bias yarns depending on the horizontal movement of a heddle device which inserts bias yarns in an intersection pattern.

The background of demand for such triaxial woven fabrics lies in a rising trend to apply these fabrics to reinforced plastic materials used for aircrafts and autocars while imparting isotropy to the strength and elongation of the fabric for increasing the strength of FRP (Fiber Reinforce Plastics) even when the fabric is thin and reducing the weight thereof.

It is a matter of course that the tetraaxial fabric is superior to the triaxial one in respect of isotropy of strength and elongation.

However, as described above, tetraaxial fabrics have scarcely been found up to now except a small amount of tetraaxial knitted fabrics and those knitted purely tetraaxially are found among only handicraft, which are exceedingly low in productivity, and a method to knit the tetraaxially arranged yarns into a sheet of fabric by the Ruschel knitting machine is inescapable from such disadvantages as complicated machine mechanism, low productivity, collapse of the entire texture of the fabric with breakage of the knitting yarn (For example, Textile Month. May 1986, pp. 6 - 7).

Though there are disclosures describing the triaxial weaving machine detailedly to some extent, it has been experimentally confirmed that the machine referred to is unsuitable for stitch skipping, high speed running, and weaving of the tetraaxial fabric because of the structure thereof in which intersecting bias yarns assumed an warp ends are shifted right and left by the movement of heddles as described above.

3. Summary of the Invention

The present invention enables high speed weaving of tetraaxial woven fabric of a unique structure with the development of novel devices of bias yarn feeding, traversing, and heddles that have never been provided by the prior art.

A tetraaxial woven fabric according to the present invention is characterized by comprising warp ends (1), weft ends (2), and upper and lower bias yarns (3) and (4), respectively, crossing each other and running bias with respect to warp and weft ends (1), (2), that is, yarns running in the directions along four levels and four axes, in which upper yarns are interlaced with lower yarns to interpose the other two kinds of yarns therebetween and compose a unit of woven fabric. Fabric structures are roughly classified into two kinds, the one comprising upper yarns as upper bias yarn (3), intermediate yarns as lower bias yarns (4) and warp ends (1), and lower yarns as weft ends (2), and the other comprising upper yarns as warp ends (1), intermediate yarns as upper bias yarns (3) and lower bias yarns (4), and lower yarns as weft ends (2).

The structure of a tetraaxial weaving machine of the present invention is a follows:

This structure is characterized by comprising: a bias yarn creel (A) carrying a large number of bobbins or a plurality of separate warp beams rotatably mounted on the surface thereof substantially perpendicular to the forward movement of the fabric; a bias yarn traversing device (B) for crosswise feeding of the upper bias yarns (3) and the lower bias yarns (4) into the weaving area approximately throughout the width thereof; a warp feeding device (C) composed of a warp beam (15) and a warp guide roll (16) for feeding the warp ends (1) into the weaving area; a heddle device (D) for the upper yarns; a weft inserting device (E), a beating-up reed device (F), and a product taking-up device (G).

The bias yarn traversing device (B) and heddle device (D) are specific.

To be concrete, a first example of the bias yarn traversing device comprises: an upper bias yarn shifting roll (11) provided with a screw-like groove (23) engraved to have pitches in number equal to at least the total number of the upper and lower bias yarns fed within the width of the weaving area; a lower bias yarn shifting roll (10) being traverse to the upper roll at groove direction and the same at rotational direction, or the same at groove direction and reverse at rotational direction, both being disposed above and below respectively; guide bars (13) in length approximate to the weaving length which are disposed fully close to the shifting rolls (10), (11) at the side facing the bias yarn creel (A); and the upper and lower bias yarn turning-over arms (26) disposed on both ends of the guide bars (13).

As a second example of the bias yarn shifting device, referred to is a device provided with guide pins (30) in number equal to at least the number of upper and lower bias yarns to be fed into the weaving area, endless chain (31) extended in the form of an ellipse; and chain sprockets (32), (33) disposed at both ends of the ellipse of chain (31).

Further, a third example of the bias yarn traversing device is such that: two sheets of upper grooved shifting plates (42a), (42b) are disposed front and back, each having yarn guide grooves (41) at lower edge in number equal to at least the total number of upper and lower bias yarns fed into the weaving width for shifting the upper bias yarns (3) right and left at a distance of one groove pitch or longer; two sheets of lower grooved shfiting plates (43a), (43b) are disposed above and below the weaving area, each having yarn guide grooves (41) at uper edge for shifting the lower bias yarns right and left in the direction reverse to that in the former plates at a distance of one groove pitch or longer; and a dividing guide (44) in length slightly shorter than the width of the grooved part (41) of the upper and lowr grooved shifting plates (42A), (43a) is disposed fully close to the grooved plates (42a), (43a) at the side facing the bias yarn creel (A).

A heddle device (D), by which the upper yarns are depressed lower than the intermediate yarns for forming a shet to permit running of the weft end (2) therethrough, comprises bias yarn depressing heddles for the upper bias yarns shifted always at the rate of one stitch and warp heddles with eyelet for the warp ends (1) not shifted which ensure exact operation and increase in weaving speed.

4. Brief Description of the Drawings:

Figs. 1 through 5 are plan views of textures of tetraaxial woven fabrics according to the present invention;

Fig. 6 is a side view of the entire structure of a tetraaxial weaving machine;

Fig. 7 is a rear view of a bias yarn creel and bias yarn traversing device with the left side thereof omitted;

Fig. 8 is a side view of a turning-over arm and nearby parts for turning over the upper bias yarn so that the upper bias yarn may be turned into a lower bias yarn (or vice versa);

Fig. 9 is a perspective view of a tetraaxial woven fabric shown in Fig. 1 under weaving operation:

Fig. 10 is a side view thereof;

Figs. 11 and 12 are views of a tetraaxial woven fabric shown in Fig. 2 under weaving operation;

Figs. 13 and 14 are views of a tetraaxial woven fabric shown in Fig. 3 under weaving operation;

Fig. 15 is a front view of a second example of the bias yarn traversing device;

Fig. 16 is a perspective view of a thrid example of the bias yarn traversing device;

Fig. 17 is a side view of the bias yarn traversing device operating at the time of weft insertion; and

Fig. 18 is a side view thereof at the time of rightward and leftward shift of upper and lower bias yarns.

5. Detailed Description of the Invention:

Texeture of tetraaxial woven fabrics according to the present invention are as shown in plan views in Figs. 1 through 5.

In Fig. 1, the upper yarns are upper bias yarns (3) running from the left top to the right bottom in the drawing. Below the upper bias yarns (3), the lower bias yarns (4) run and warp ends (1) run further below. Among these yarns, the lower bias yarns (4) and warp ends (1) are intermediate yarns running on respective two levels in mere flat stack relation without interlaced with any other yarns. The lower yarns are weft ends (2), and the upper bias yarns (3) pass through under the weft ends (2), return to the upper level, press down the warp ends (1) and the lower bias yarns (4), and then again pass through under the next weft ends (2). The intermediate yarns on the respective two levels are positionally fixed at intersections of the upper bias yarns (3) and weft ends (2) and cause no slippage of stitches. This texture is woven by depressing the upper bias yarns (3) for providing a shed and inseting weft ends (2) through the shed thus formed. Shedding at the upper bias yarns (3) depends on the bias yarn depressing heddles as shown in Figs. 9 and 10.

The texture in Fig. 2 corresponds to the so-called plain weave and is composed of warp ends (1) as upper yarns and weft ends (2) as lower yarns, in which the warp ends (1) only alternately form a shed and the intermediate yarns, that is, the upper and lower bias yarns (3) and (4), respectively, are interposed between the warp and weft ends while kept in a mere flat stack relation. A weaving machine to be used is of the structure in which only the warp ends (1) alternately form a shed by means of eyelet heddles as shown in Figs. 11 and 12.

In the case of the texture shown in Fig. 3, the upper yarns are warp ends (1) which are all depressed to form a shed repeatedly and intersect the weft ends (2) for interposing the bias yarns running on the respective two levels, the weaving process being shown in Figs 13 and 14.

The textures shown in Fig. 4 and Fig. 5 are examples of weave, in which the pitch between bias yarns is reduced to a half of that shown in Figs. 1 through 3 and; doubled in density; Fig. 4 shows that the warp ends (1) are all depressed for shedding and intersect the weft ends (2); and, in Fig. 5, the warp ends (1) form a shed at every other line of weft end (3) and intersect the weft ends.

A description of a tetraaxial weaving machine according to the present invention will be made with reference to Fig. 6 through 18.

The tetraaxial weaving machine of the present invention is characterized by comprising: a bias yarn creel (A) carrying a large number of bobbins or a plurality of a separate warp beams rotatably mounted on the surface thereof substantially perpendicular to the forward movement of the fabric; a bias yarn traversing device (B) for crosswise feeding of the upper bias yarns (3) and the lowr bias yarn (4) into the weaving area approximately throughout the width thereof; a warp feeding device (C) composed of a warp beam (15) and a warp guide roll (16) for feeding the warp ends (1) into the weaving area; a heddle device (D) for the upper yarns; a weft inserting device (E), a beating-up reed device (F), and a product taking-up device (G); the details thereof being described by way of an example shown in Figs. 6 and 7.

Referring to the device shown in Figs. 6 and 7, a large number of bias yarn bobbin (5) are arranged on the outer periphery of an annular bias yarn creel (A) supported by a plurality of supporting rollers (8) and rotated by the internal transmission gear (9) connected to a driving device. These bias yarn bobbins (5) may be replaced by a plurality of separate warp beams. The bias yarn traversing device (B) is of the following structure. On the central portion of the bias yarn creel (A) and in the horizontal direction, an upper bias yarn shifting roll (11) and lowe bias yarn shifting roll (10), both being provided with screw-like grooves (23) engraved at the same pitches in the same direction and having the number of pitches equal to at least a half of the number of bias yarns to be fed within the weaving width, are rotated in the directions reverse to each other by the driving power transmitted through the shifting roll driving gear (12) lying thereabove. A guide bar (13) is disposed near the sides of the upper and lower bias yarn shifting rolls facing the creel, and supported by guide bar supporting arms (14) so as to be shifted intermittently (or continuously when required) at a picking pitch. Rotations of the bias yarn shifting rolls (11), (10) are synchronous with those of the creel. An upper and lower bias yarn turning-over arm (26) to rotate radially with respect to the guide bar is provided on the end of the guide bar and the action thereof will be described later.

The warp ends (1) are guided from the warp beam (15) to run below the upper and lower bias yarns (3), (4) by the warp feeding device (C) comprising the warp guide roll (16) and others, and, into a shed formed by the shedding heddles, a weft end (2) is inserted with the shuttle or rapier, when the reed device (F) for beating-up operate as follows: Any of the upper and lower reed (21) and (22), respectively, is always positioned at the fell of cloth for providing a shed between warp ends (1), for example, when the lower reed (22) lies at the fell of cloth, the upper reed (21) operates for inserting a weft end (2) and, on the way of weft insertion, the lower reed downwardly leaves from warp ends at the fell of cloth and approaches the heddles in preparation for weft insertion into the next shed. The upper and lowr reeds (21), (22) alternately

enter into the warp sheet near the heddles for weft insertion while maintaining parallelism between warp ends as well as bias yarns at every rotation of the weaving machine, that is every weft insertion operation and operate to support bias yarns and warp ends at the fell of cloth. All yarns are woven into a fabric through the upper and lower reeds (21), (22) and the fabric thus woven up is wound as a final product (24) on the takingup roll (25) which is a principal member of the product taking-up device (G).

Upper bias yarns (3) and lower ones (4) are inserted into the weaving area to extend perpendicular to each other and, for this purpose, guided from the bias yarn bobbins (5) on the outer periphery of the annular creel (A), through the tension guides (6) and slackness removing springs (7), to the bias yarn traversing device (B), that is, to the screw-like grooves (23) of the upper and lower bias yarn shifting rolls (11) and (10), respectively, from above and below the guide bar (13) (See Figs. 7 and 9). The shifting rolls provided with screw-like grooves running in the same direction (for example, right hand screw) and at the same pitches are rotated in the opposite directions, and, therefore, the upper bias yarns (3) are shifted to the right side in Fig. 7 in succession whereas the lower bias yarns (4) to the left side at weaving pitches, whereby the bias yarn creel A rotates clockwise synchronously with the shifting rolls at the same pitches as above. The upper bias yarn (3), upon arrival at the right end in Fig. 7 slips off the end of the guide bar (13); positioned as shown by an alternate long and short dash line in Fig. 8; caught by the upper and lower bias yarn turning-over arm (26) which is in intermittent motion; shifted downwardly as shown by an alternate long and two short dashes line; further shifted to the side of the lower bias yarn shifting roll (10) and turned into a lower bias yarn (4); then guided to the screw-like groove (23) of the lower bias yarn shifting roll (10); disengaged from the arm (26); and shifted to the left side successively at weaving pitches.

The abovesaid bias yarn traversing device (B) can be modified into another structure. An example is as shown in Fig. 15 and comprises bias yarn guide pins (30) in number equal to at least the number of bias yarns to be fed into the weaving area, and endless chain (31) in the form of an ellipse running on a plane perpendicular to the weaving width, and chain sprockets (32), (33) disposed on both ends of the ellipse of chain, in which bias yarns fed from above and those from below into the weaving area serve as upper bias yarns (3) and lower bias yarns (4), respectively.

A third example of the bias yarn traversing device will be described referring to Figs. 16 through 18.

This transversing device is characterized by comprising: two sheets of upper grooved shifting plates (42a), (42b) disposed front and back in the space above the weaving level and provided with yarn guide grooves (41) in number equal to at least a half of total number of upper and lowr bias yarns (3) to be fed into the weaving width which are engraved at lower edge for shifting the upper bias yarns right and left at one-groove pitch or longer; two sheets of lower grooved shifting plates (43a), (43b) disposed front and back in the space below the weaving level and provided with similar yarn guide grooves engraved at upper edge for shifting the lower bias yarns (4) right and left in the direction reverse to that of the upper grooved shifting plates (42a), (42b) at one-groove pitch or longer; and a dividing guide (44) slightly shorter than the length of the yarn guide groove part (41) of the upper and lower grooved shifting plates (42a), (43a) which is disposed fully close to the upper and lower shifting plates (42a), (43a) at the side facing the bias yarn creel (A).

Detailedly, the upper and lower bias yarns (3) and (4) fed from the bias yarn creel (A) are respectively divided to run above and below by the dividing roller (44) disposed horizontally ahead of the center of the creel (A) and having a length approximate to the weaving length. The upper and lower bias yarns (3), (4) are extended to the fell of cloth (48) while constantly pressed from above and below by the upper and lower grooved shifting plates (42b), (43b) provided with yarn guide grooves (41), (41) each in number equal to at least a half of the number of the upper and lower bias yarns (3) or (4) to be fed throughout the weaving width, and fixed ny the metallic fixtures (45) with the yarn guide grooves (41), (41) opposed to each other. In the space extending from the dividing guide (44) to the upper and lower grooved shifting plates (42b), (43b), associative upper and lower grooved shifting plates (42a), (43a) having yarn guide groove (41), (41) in number equal to that of the former plates (42b), (43b) are disposed close to the former plates with the guide grooves (41), (41) opposed to each other.

The upper and lower grooved plates (42a), (43a) are supported by a guide pole (49) to be shiftable vertically and horizontally through a guide hole (49a) of the post (49), and, as shown in Fig. 17, are adapted to perform a square-path movement as travelling upward, righward (leftward), downward, and leftward (rightward) by a driving mechanism (W) as shown in Fig. 16 every time when the warp ends (1) fed from the warp feeding device (C) consisting of the warp beam (15) and the warp guide roll (16) are downwardly drawn by the needle-heddles (27) and a weft end (2) is inserted by the weft insertion device (E) through

the upper and lower bias yarns (3), (4). Though only one driving mechanism (W) for the lower shifting plate (43a) is shown in Fig. 16, the similar mechanism for the upper grooved shifting plate (42a) is provided in a higher position.

As shown in Fig. 18, the upper grooved shifting plates (42a) descends and retains, at yarn guide grooves thereof, each and every upper bias yarns (3) having been retained by the upper grooved shifting plate (42b) on the rear side, furrher descends to release the yarns from the upper plate (42b), moves rightward at a distance longer than one groove pitch and ascends, and adapts the upper yarns (3) to be retained by the guide grooves (41) of the upper shifting plate (42b) lying in a position moved at a distance longer than one groove pitch.

The upper grooved shifting plate (42a) further ascends, leaves from the upper bias yarns (3), as shown in Fig. 17 and, after moving leftward at a distance longer than one groove pitch, returns to the initial position. At the same time, the lower grooved shifting plate (43a) operates in a mode contrary to that of the abovesaid upper shifting plate (42a) in order to shift leftward the lower bias yarns in succession. In this way, the upper and lower yarns (3), (4) are respectively shifted in the opposite directions and, every time of completion of weft insertion into a shet formed by the warp ends (1) and the upper and lower bias yarns (3), (4), the warp ends (1) rise above the upper and lower bias yarns (3), (4) (as shown in Fig. 18).

The upper grooved shifting plate (42a) descends and shift, while depressing, the upper bias yarns (3) rightward in succession and, on the contrary, the lower shifting plate (43a) ascends and shifts the lower bias yarns (4) leftward in succession, whereby the upper and lower bias yarns (3), (4) intersect each other in bias relation with respect to the warp and weft ends (1) and (2), respectively, at the fell of cloth to weave up a tetraaxial fabric.

The driving mechanism (W) for driving the lower grooved shifting plate (43a) as shown in Fig. 16 will be described.

A cam driving shaft (53) is rotated by the rotation of the main shaft (50) of the weaving machine through gears I (51) and II (52). The cam driving shaft (53) is fitted with a cam (60) for horizontally shifting the lower grooved shifting plate (43a) and another cam (61) for vertical shift thereof.

The horizontal shifting cam (60) causes a cam lever (62a), which is formed into a torsion spring (68) at the middle portion and provided with a cam roller (64a) at the lower part, to reciprocate in the horizontal direction. Since the tip of the cam lever (62a) is connected to the lower grooved shifting plate (43a) at an acting point (65), the lower shifting plate (43a) horizontally reciprocates in association with the movement of the cam lever (62a). The torsion spring (68) functions to constantly press the cam roller (64a) to the horizontal shifting cam (60).

The vertical shifting cam (61) causes a cam roller (64b) positioned at the end of a cam lever (62b) having a fulcrum (67) at the middle part thereof to swing vertically, whereby a cam rod (63) bearingly supported at the other end of the cam lever (62b) vertically reciprocates. Since the cam rod (63) is connected to the lower grooved shifting plate (43a) at the acting point (65) on the tip thereof, the lower plate (43a) vertically reciprocates in association with the movement of the cam rod (63). The cam roller (64b) is constantly pressed to the vertical shifting cam (61) by a coiled spring (69) on the other end of the cam lever (62b) to which the cam roller (64) is fixed.

The driving mechanism (W) of such structure as above provides a fabric having texture composed of upper and lower bias yarns (3), (4) running crosswise with respect to warp and weft ends (1), (2).

Turning-over of the upper and lower bias yarns (3), (4) is performed through the steps that the dividing guide (44) is made slightly shorter than the yarn guide groove parts (41), (41) of the upper and lower grooved shifting plates (42a), (43a) so that the upper and lower bias yarns (3), (4) having been shifted to the yarn guide grooves (41) at both ends of the guide may be shifted at one more groove pitch and released from the dividing guide (44). In other words, during the revolution of the bias yarn creel (A), when the bobbin (5), which is mounted on the bias yarn creel (A) and feeds, through the balancing spring (57), the upper and lower bias yarns (3), (4) to pass through the guide grooves (41), (41) on both side of the shifting plates, reaches a position Y beyond a limit while skipping the horizontal side extremity X of the creel as shown in Fig. 16, the upper and lower bias yarns (3), (4) on both ends of the shifting plates are released from the dividing guide (44) and turned over upside down. The balancing spring 57 constantly exerts tension on the upper and lower bias yarns running between the bias yarn bobbins (5) and the yarn guide grooves (41), (41) of the upper and lower grooved shifting plates (42a), (43a). The upper and lower bias yarns (3), (4) are successively turned over and obliquely run from right to left or vice versa, thereby composing a fabric.

In addition to the above example of the square-path movement of the upper and lower grooved shifting plates (42a), (43a) as described above, the other three modes of movement are possible as follows:

1 The upper and lower grooved shifting plates (42b), (43b) are set unmovably and the other ones (42a), (43a) are adapted to move along a triangular path running in the directions reverse to each other in the space in front of the former shifting plates (42b), (43b). Referring to the upper grooved shifting plate (42a), it descends, stops after releasing the upper bias yarn from the guide groove of the upper shifting plate (42b), ascends obliquely and upwardly, and, on the way of ascending, places the released upper bias yarn (3) on a guide groove on the left side one or more grooves distant from the first groove, further ascends leftwardly and upwardly to the initial position, thereby performing a right-angled triangular-path circulatory movement.

2 Similarly to the triangular-path circulatory movement as described in the paragraph 1, the upper shifting plate (42a) is obliquely lowered from the upper right-hand position to the lower left-hand position toward the upper bias yarn (3) retained in the guide groove of the stationary upper shifting plate (42b), receives the yarn (3) on the way of lowering and releases the yarn from the groove of the upper plate (42b), stops after continuous oblique ascending to the lower left-hand position while retaining the yarn (3), obliquely ascends to the upper left-hand position and shifts, on the way of ascending, the yarn from the groove of the upper plate (42b) to the other groove on the left side one or more grooves distant from the upper shifting plate (42b), further continues oblique ascending to the upper left-hand position, and, after reaching the initial level, moves rightward to return to the initial position, thereby performing an equilateral triangular-path movement.

3 Differently from 1 and 2 described above, the upper grooved shifting plates (42a), (42b) and the lower plates (43a), (43b) are all movable. The upper and lower plates (42a), (43a) in the forward position move up and down in the opposite directions whereas the other plates (42b), (43b) in the rear position move right and left in the opposite directions for shifting the upper and lower bias yarns right and left in the opposite directions in a distance of one or more groove pitches. The movement in this case will be described referring to the upper grooved shifting plates (42a), (42b) as follows:

The upper bias yarn (3) retained in the guide groove of the upper plate (42b) movable only right and left is released therefrom by lowering of the upper plate (42a) movable only up and down. While the upper yarn (3) is kept released, the upper plate (42b) moves rightward and, at a position reached thereby, catches, with the guide groove thereof, the upper yarn having been raised with the rise of the upper plate (42a) which has been lowered before. Even after placing the upper yarn (3) in the groove of the upper plate (42b), another upper plate (42a) rises to the upper limit so as not to interfere with the right and left movement of the upper bias yarn (3). The upper plate (42b) having caught the upper bias yarn (3) moves leftward at a distance of one or more groove pitches, when the upper plate (42a) having reached the upper limit lowers and, while retaining the yarn with a groove one or grooves distant from the first groove, descends to the lower limit. Afterward, the similar operation is repeated to shift the upper yarns (3) at a distance of one or more groove pitches in turn. The pitch of shift is determined by the number of bias yarns per unit length of the fabric.

At the time of movement of the grooved shifting plates as describe above, it is necessary to constantly press the upper and lower bias yarns against the grooves (41) of the upper plates (42b), (43b), and the action required is taken by means of the dividing guide (44) which will be described later. Since the structure of the driving mechanism (W) for the square-path movement was concretely described first, the other structures for movement of the grooved shifting plates will easily be understood and is omitted from description.

A method of weaving will be described.

Figs. 9 and 10 illustrate the state of weaving by means of bias yarn pushing heddles to form a shed while moving the upper bias yarns (3) only, in which the upper bias yarns (3) are on the highest of weaving levels with the lower bias yarns (4) and warp ends (1) positioned lower in sequence, and the upper bias yarns (3) on the highest level are pressed downward lower than the other three kinds of yarns for shedding (as shown by the alternate long and short dash line in Fig. 10) and to insert the weft end (2) therethrough by the rapier or shuttle (not shown). Depression of the upper bias yarns (3) for shedding depends on the heddle device (D) exclusive for the upper yarns.

A large number of pushing heddles (18) fixed to a heddle frame (19) depress all the upper bias yarns (3) simultaneously for shedding and a weft end (2) is run through the shed by an ordinary picking device (E) (not shown). The state of operation is shown in Fig. 9. A textraaxial fabric woven by this method, therefore, is in such structure that all upper bias yarns (3) run in the same direction, always press the lower bias yarns (4) (bias yarns crossing perpendicularly to upper ones) and warp ends (1), and then sink to the lower position, the level of the weft ends (2) being below that of the warp ends (1) as illustrated in Fig. 1.

Weaving may depend on shedding of the upper bias yarns at every other end and alternately, and, for this purpose, the pushing heddles (18) as shown in Figs. 9 and 10 are disposed for every other end and the heddle frames (19) are alternately shifted right and left at a distance of one pitch.

Figs. 11 through 14 are views showing a method of weaving using the warp heddles, among which Figs. 11 and 12 show alternate shedding with warp ends interlaced with weft ends in one-up-one-down pattern to provide the so-called plain weave having the upper and lower bias yarns woven thereinto while merely laid flat between the warp and weft ends. In this case, alternately performed are shedding by means of front needle heddles (27) of the heddle frame (19) two rows (one row allowable) ahead of the warp heddle frame (19) shown in Fig. 11, shed closing as shown in Fig. 12, and shedding by the rear needle heddles (28) as shown in Fig. 11, the process being usual shedding and readily understood. A fabric texture thus produced is as shown in Fig. 2.

Figs. 13 and 14 show a state in which all warp ends are shedded simultaneously, however, the state is not so different from that of plain weave as described above except a difference in the movement of heddle frames (19). A fabric texture obtained is as shown in Fig. 3, which is composed of warp ends (1), upper bias yarns (3), lower bias yarns (4), and weft ends (2) layered in the order from top to bottom.

The reference character 20 in Figs. 11 and 13 indicates a picking rapier.

A textraaxial woven fabric of the present invention as has detailedly been described as above possesses isotropy in strength and elongation characteristics and, even thinner than the conventional type fabrics, exhibits isotropic nature of higher level. A tetraaxial weaving machine of the present invention equipped with a novel device of bias yarn feeding and traversing device enables high speed weaving advantageous for mass production and consequent cost reduction.

Claims

1. A tetraaxial woven fabric characterized by being composed of tetra-layered and tetraaxially-directed yarns including warp ends (1), weft end (2), upper bias yarns (3), and lower bias yarns (4), the latter two (3), (4) being oblique with respect to the former two (1), (2), wherein upper yarns are interlaced with lower yarns while interposing the other two kinds of yarns therebetween so as to be united together.

2. A tetraaxial woven fabric as set forth in Claim 1, wherein the upper yarn corresponds to the upper bias yarn (3), the intermediate yarn to the lower bias yarn (4) and the warp end (1), and the lower yarn to the weft end (2).

3. A tetraaxial woven fabric as set forth in Claim 1, wherein the upper yarn corresponds to the warp end (1), the intermediate yarn to the upper bias yarn (3) and lower bias yarn (4), and the lower yarn to the weft end (2).

4. A tetraaxial weaving machine characterized by comprising: a bias yarn creel (A) carrying a large number of bobbins or a plurality of separate warp beams which are rotatably disposed on an imaginary plane substantially perpendicular to the direction along which the woven fabric is taken up; a bias yarn traversing device (B) for feeding intersecting yarns into an area of the substantially equal to the width of fabric to be woven; a warp feeding device (C) consisting of a warp beam (5) for feeding warp ends into the weaving area and a warp guide roll (16); a heddle device (D) for upper yarns; a weft picking device (E); a beating up reed device (F); and a product taking-up device (G).

5. A tetraaxial weaving machine as set forth in Claim 4, wherein said bias yarn traversing device (B) is provided with: an upper bias yarn shifting roll (11) having screw-like grooves (23) with pitches in number equal to at least a half of the number of bias yarns fed into the weaving area throughout the width thereof; a lower bias yarn shifting roll (10) having screw-like grooves and being reverse to said upper roll at groove direction whereas the same at rotational direction, or the same at groove direction whereas reverse at rotational direction, both rolls being disposed above and below the weaving area; a guide bar (13) of the length substantially equal to the width of weaving area disposed fully close to said shifting rolls at the side facing said bias yarn creel (A); and bias yarn turning-over arms disposed on both ends of said guide bar (13).

6. A tetraaxial weaving machine as set forth in Claim 4, wherein said bias yarn traversing device (B) comprises guide pins (30) in number equal to at least the number of bias yarns fed into the weaving area, an endless chain (31) in the form of an ellipse rotating on a plane perpendicular to the width of weaving area; and chain sprockets (32), (33) disposed on both ends of said ellipse of chain.

7. A tetraaxial weaving machine as set forth in Claim 4, wherein said bias yarn traversing device (B) comprises: two sheets of upper grooved shifting plates (42a), (42b) disposed front and back, each having, at lower edge, yarn guide grooves (41) in number equal to at least a half of the total number of upper and lower bias yarns (3) fed into the weaving area throughout the width thereof and

shifting the upper bias yarns right and left at a distance of one or more groove pitches; and similar two sheets of lower grooved shifting plates (43a), (43b) disposed front and back, each having, at upper edge, yarn guide grooves (41) and shifting the lower bias yarns (4) right and left at a distance of one or more groove pitches in the direction reverse to that of the former plates, the former two sheets and the latter two being disposed above and below the weaving area, respectively, and wherein a dividing guide (44) slightly shorter than said yarn guide groove part of upper and lower bias yarn shifting plates (42a), (43a) is disposed fully close to said plates at the side facing said bias yarn creel (A).

8. A tetraaxial weaving machine as set forth in Claim 4, wherein said heddle device (D) corresponds to a bias yarn pressing heddle (18) or needle heddle (27) for warp end.

Fig. 1

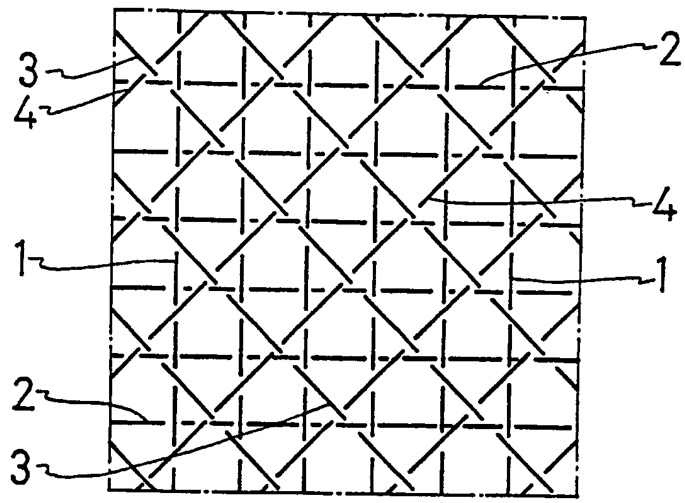


Fig. 2

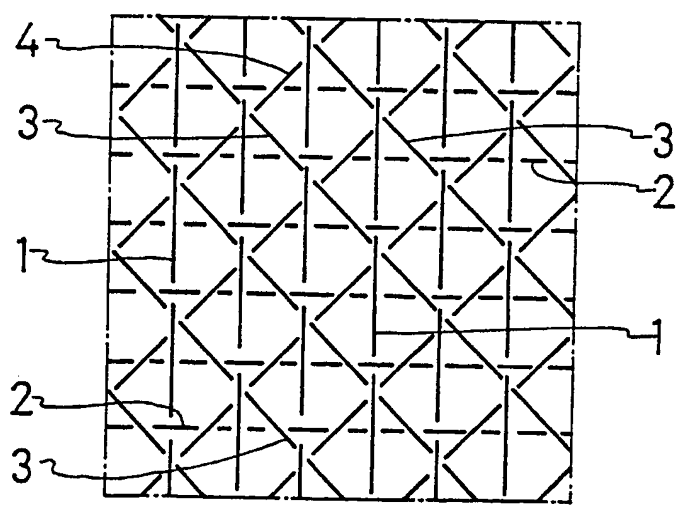


Fig. 3

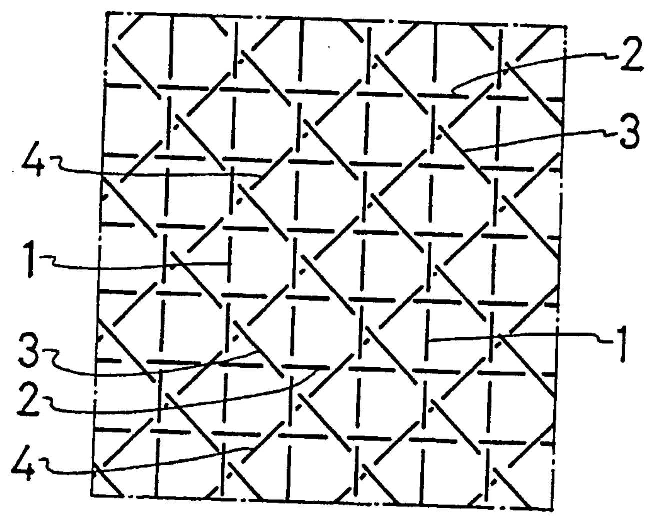


Fig. 4

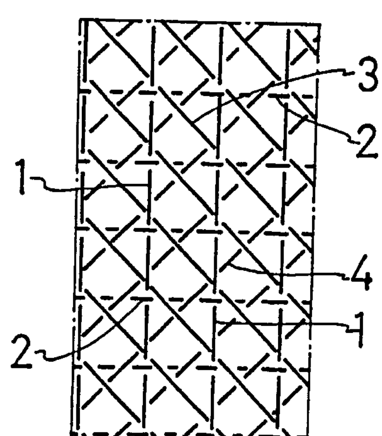


Fig. 5

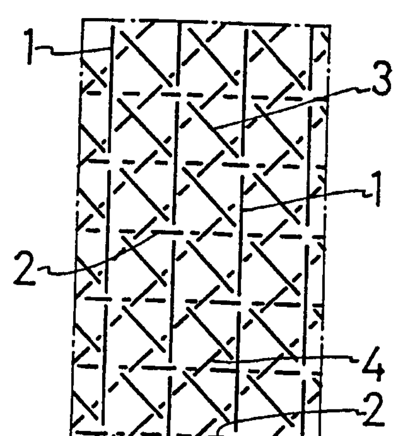


Fig. 6

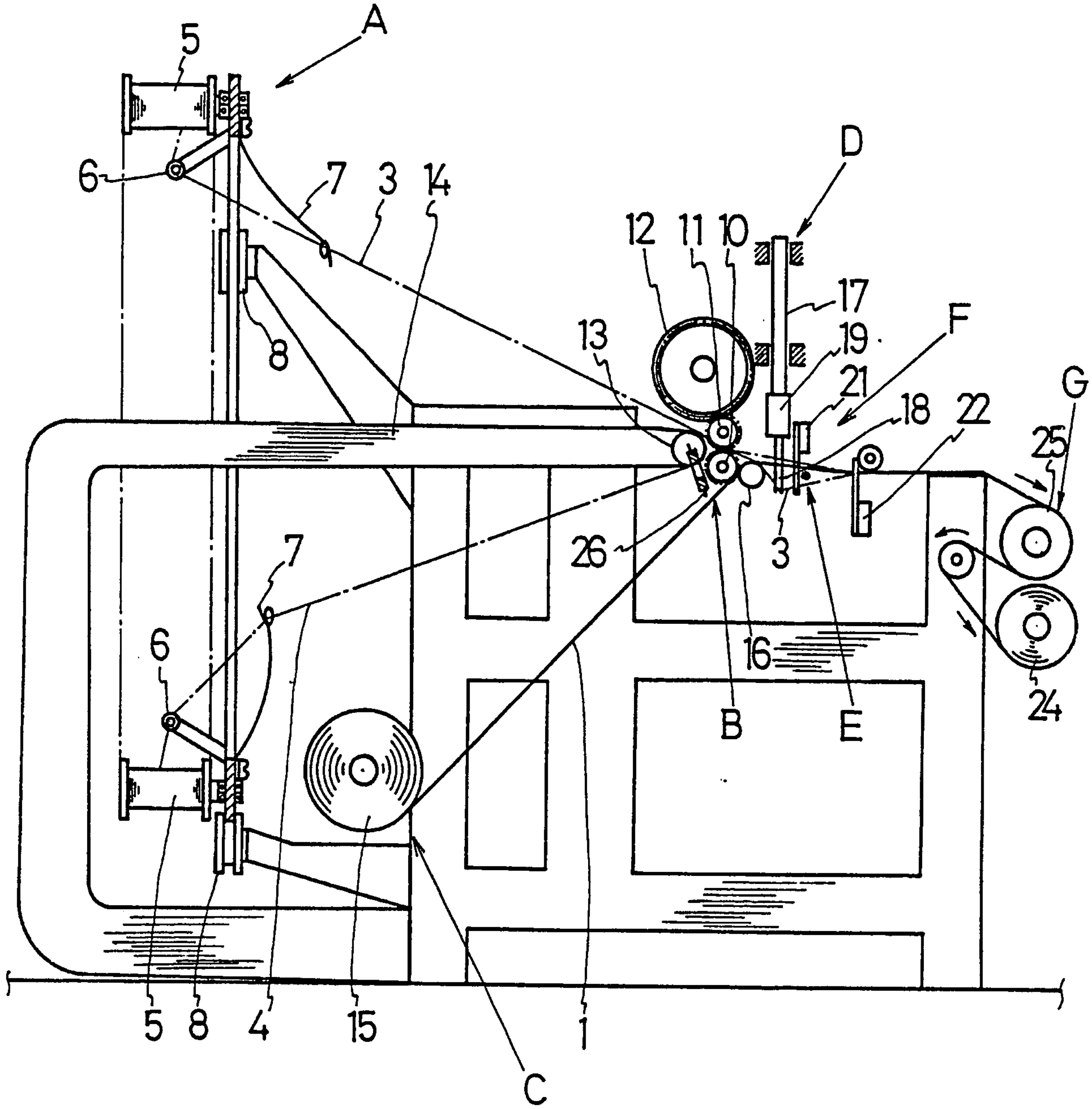


Fig. 7

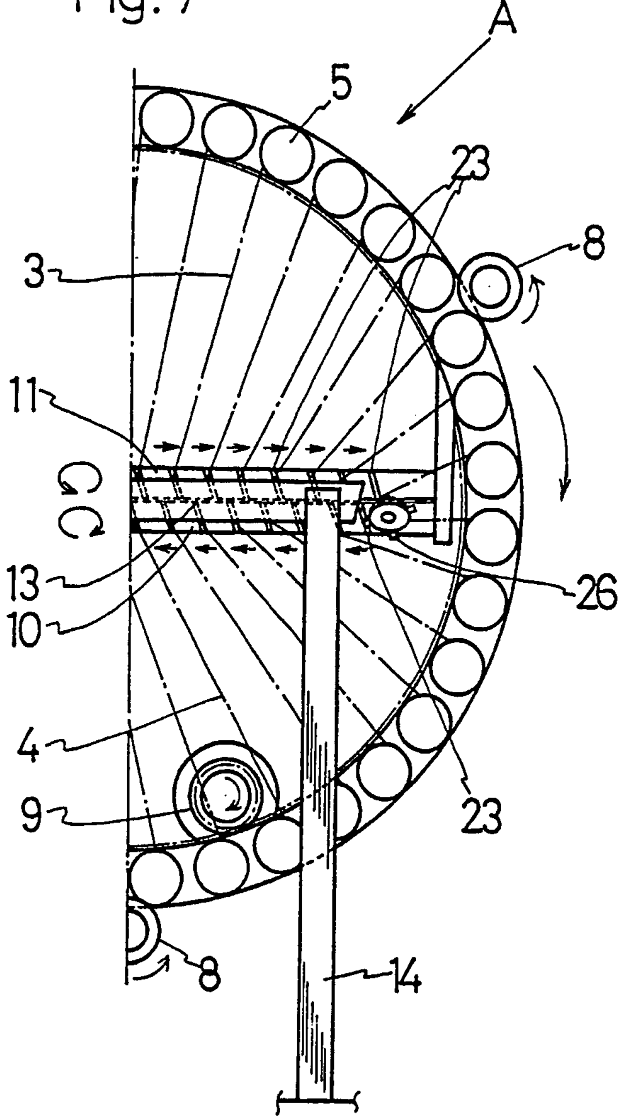


Fig. 8

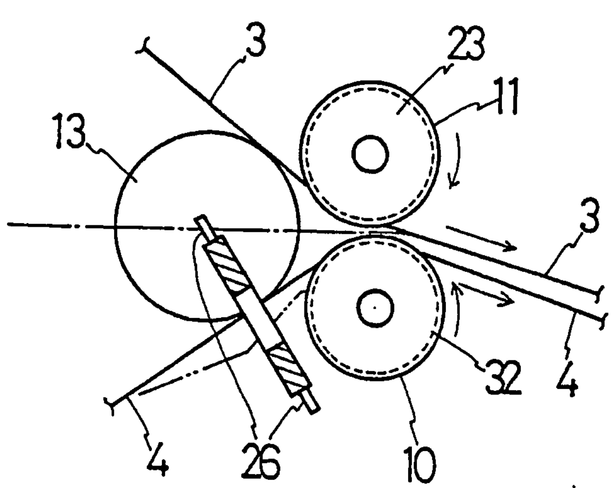
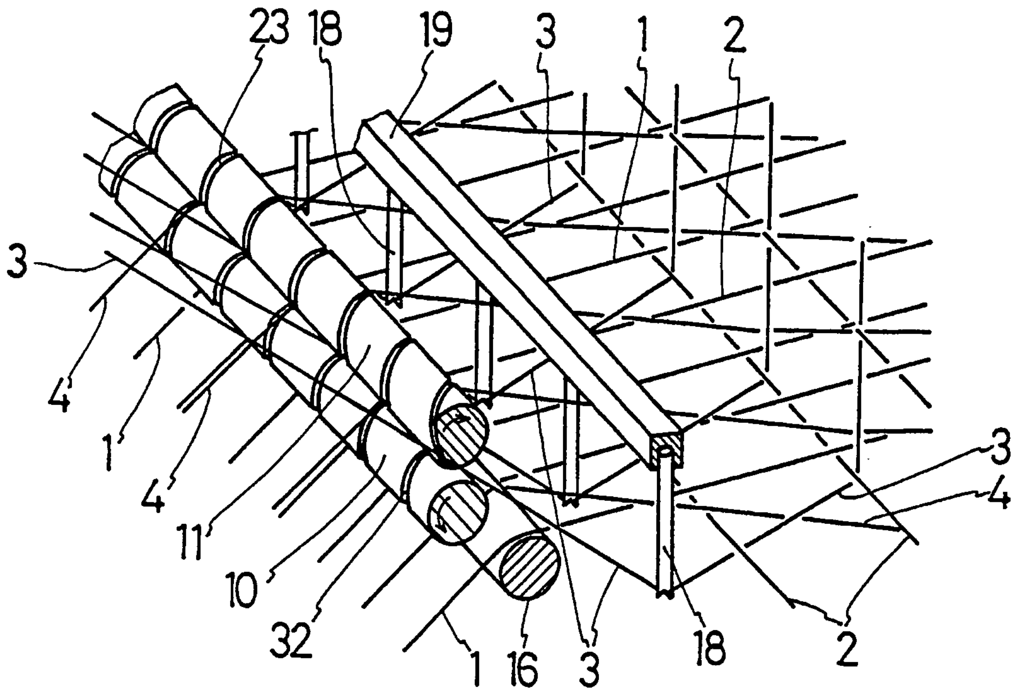


Fig. 9


23
18
19
3
1
2
3
4
1
4
11
10
32
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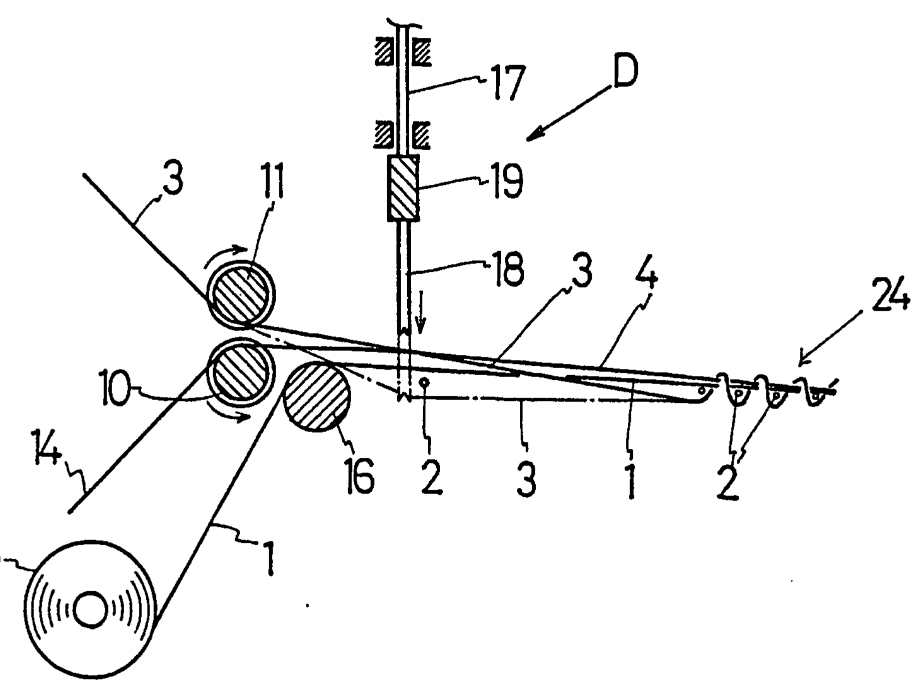
16
3
18
2
3
4

Fig.10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D
19
3
11
18
3
4
24
10
14
16
2
3
1
2
15
1

Fig. 11

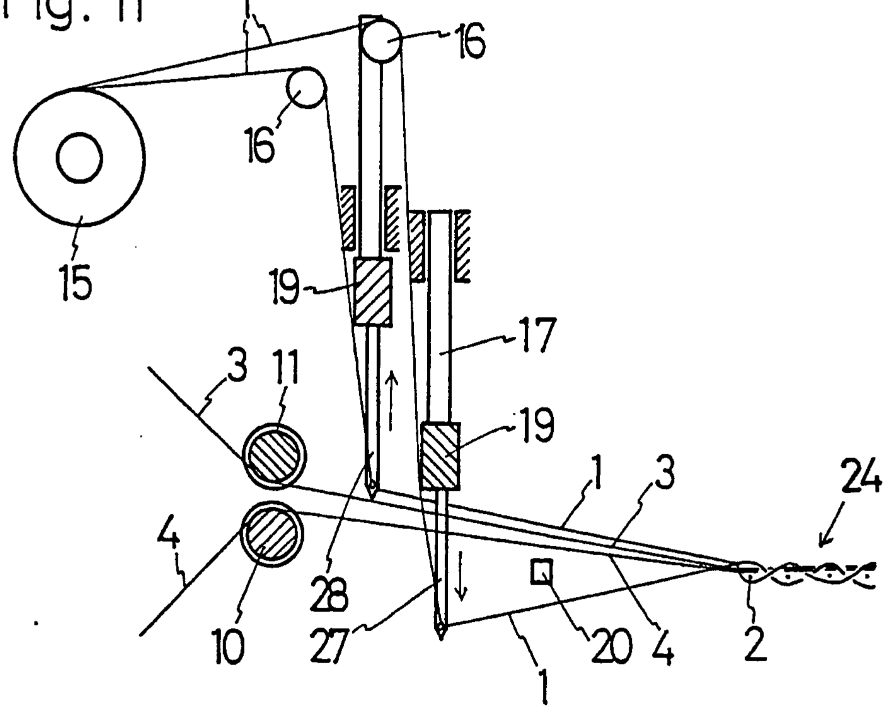
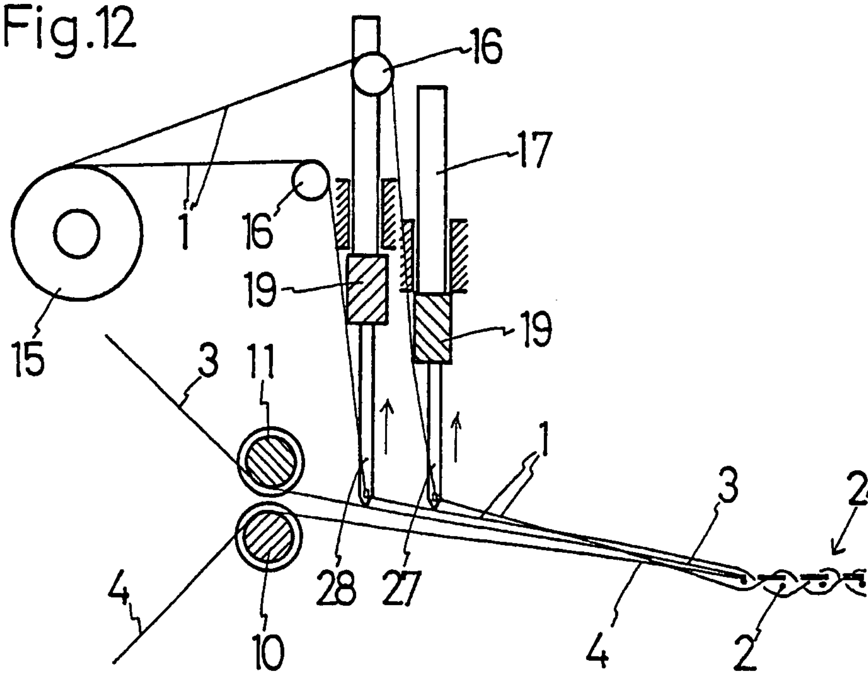

1
16
16
15
19
17
3
11
19
1
3
24
4
28
27
10
20
4
2
1

Fig.12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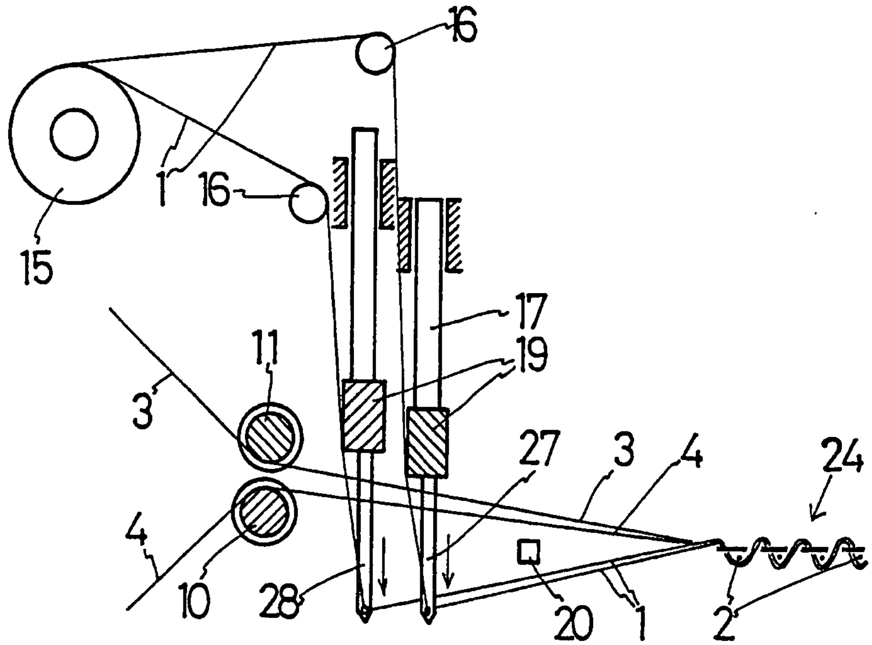
2

Fig.13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28
20
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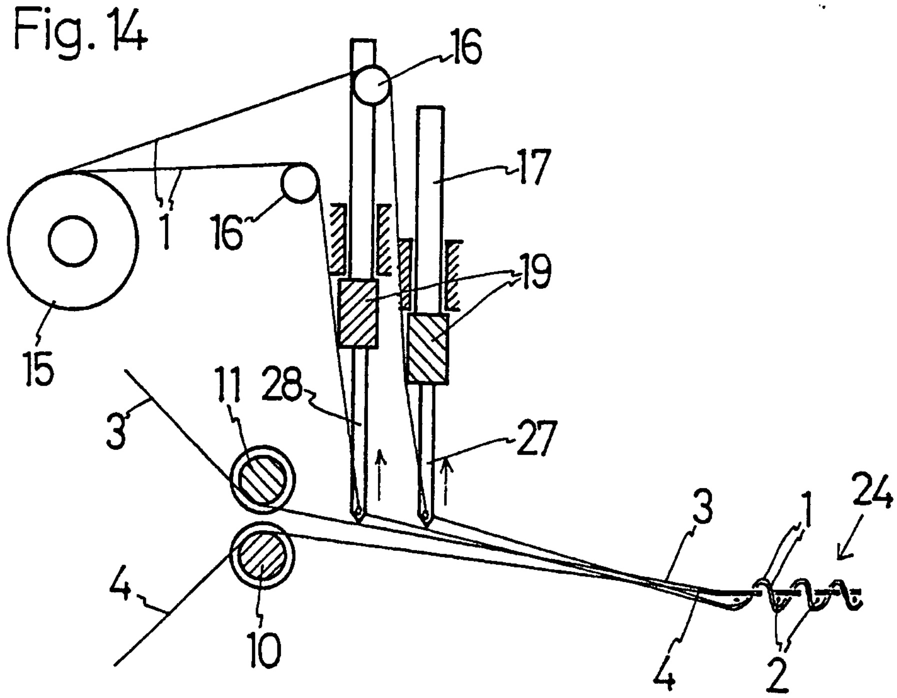
2

Fig.14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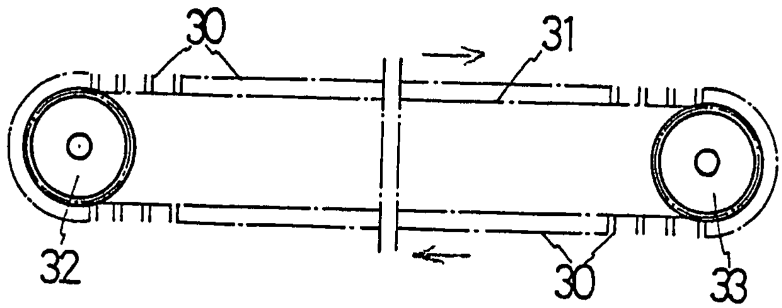
10
4
2

Fig.15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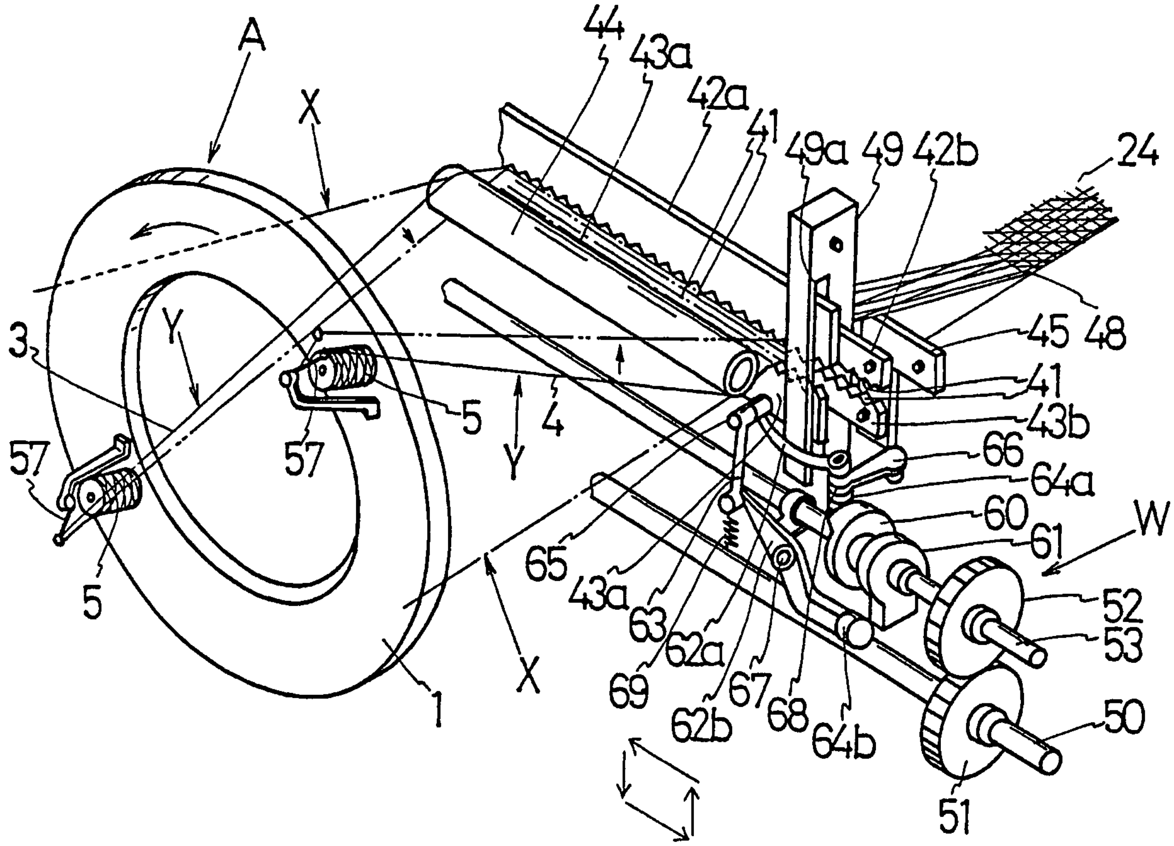
32
30
33

Fig.16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49a
49
42b
24
3
Y
5
4
45
48
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43b
66
64a
60
61
W
57
57
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Y
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5
X
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64b
50
51

Fig.17

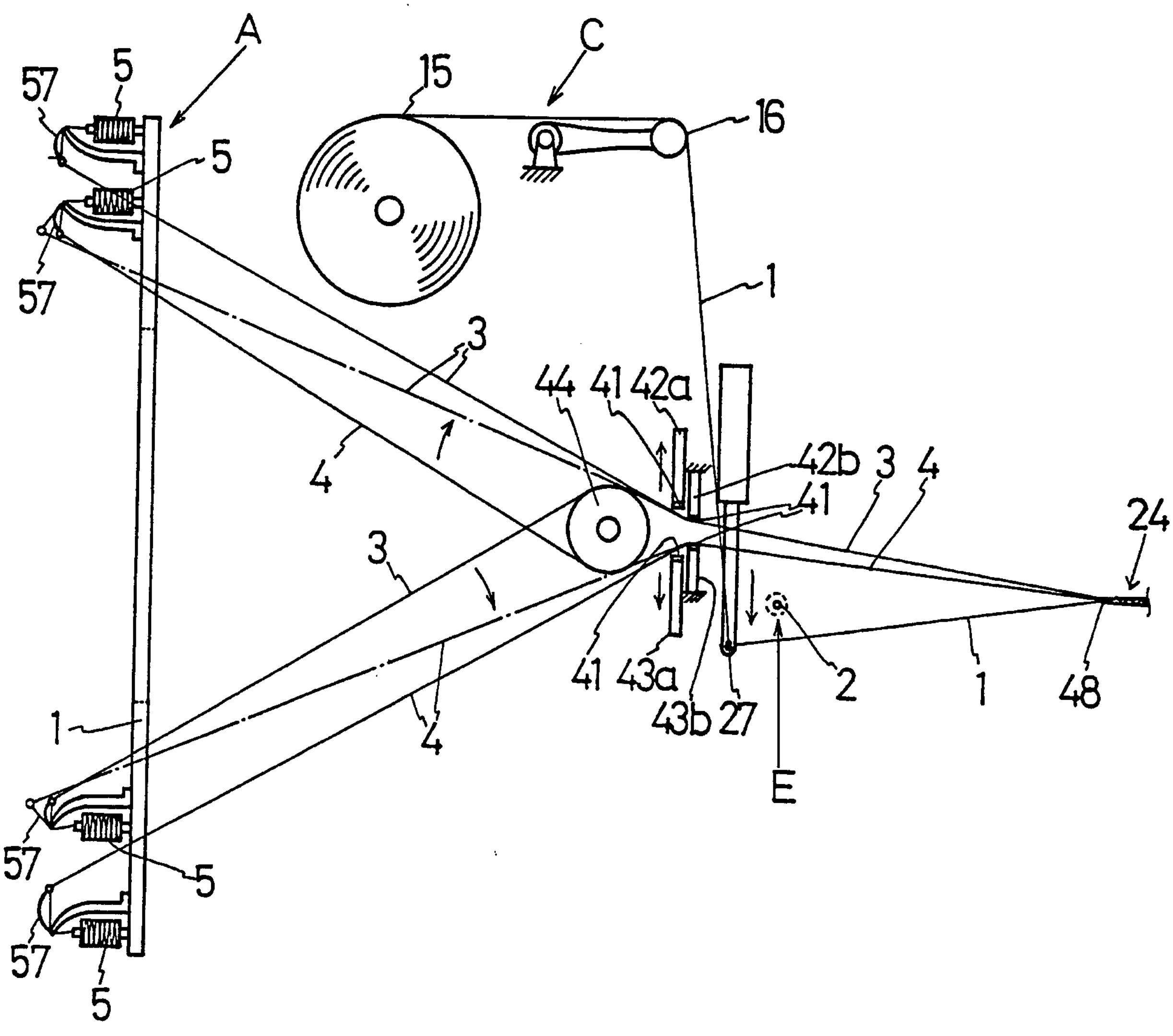
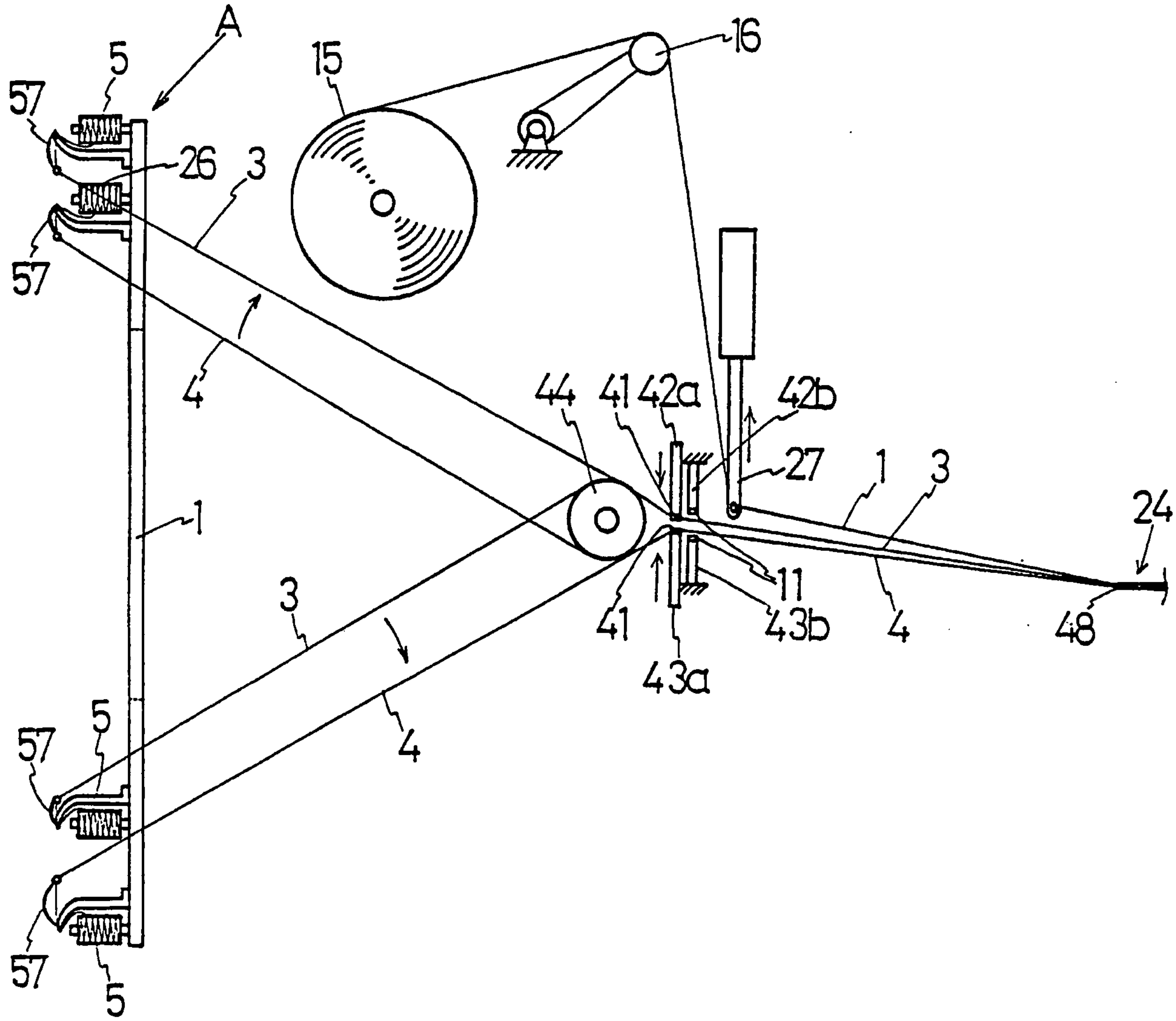


Fig.18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4
48
43a
3
4
57
5
57
5